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Lubrication

A Technical Publication Devoted to the Selection and Use of Lubricants

THIS ISSUE

Cold Weather, Your Car and Its Operation

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Cold Weather, Your Car and Its Operation

COLD weather operation of the motor car is a nemesis to many an owner. Beset with the problems of difficult starting, fouling of spark plugs due to carbon, dilution of motor oils, the possibility of freezing, or the thought that his gears are merely channeling through the lubricant in his gear case, his enjoyment of motoring is decidedly reduced. For the average owner has the interest of his car at heart. He wants to treat it right, to preserve its parts, to maintain it in condition conducive to maximum economy. There is a direct reaction upon his pocket book, and the re-sale value of his car.

How to do it, on the other hand, is frequently a point of wonderment. To merely buy "peppy gas" drain and refill his crankcase at recommended intervals with "good oil," and add a gallon or so of alcohol, etc., to his cooling system whenever he thinks necessary, does not solve the problem.

Just what the essential characteristics of this "peppy gas" should be, just what his "good oil" should be capable of withstanding, or just how much anti-freezing solution he should add to his radiator are of vital interest to him.

The ideal in modern motor car design is to render it efficient and capable of ready operation whatever the atmospheric temperature.

Certain parts of course, such as the carburetor, necessarily have had to be made capable of accurate adjustment according to the operating temperature. But on the whole the automobile of today is of so-called standardized construction insofar as adjustment to meet weather conditions is concerned.

Efficient results, however, cannot be attained simply for this reason. Attention must also be given to operating principles as involved in the handling of the fuel, lubrication of the engine, the use of anti-freezing solutions, and radiator covers, thermostats or shutters to maintain the cooling system at the proper temperature.

In fact, cold weather operation of the motor car can well be viewed from five distinct angles:

1. The gasoline and its manner of usage.
2. Lubrication requirements of the Engine.
3. Lubrication of the Transmission, Differential and Chassis Parts.
4. The Cooling System.
5. The Storage Battery and its care.

Careless operation or lack of attention to any of these details may give rise to any number of discomforting and expensive results.

Gasoline, Its Properties and Its Manner of Usage

Refinery practices have been revolutionized during the past few years. More and more has it been found possible to break down certain of the heavier distillates into gasoline by means of what is known as the "cracking" process.

As a result of such methods of refining, high

grade motor gasoline today has greater volatility with a lower end point than heretofore.

When the engine is running under normal temperature conditions, and even under moderate cold conditions, there should be no difficulty experienced with a gasoline of this character. Under extremely cold engine conditions, however, especially when starting, the amount of gasoline which will vaporize without external heat is considerably smaller than in warm weather or when the engine is hot.

Fig. 1—Example of the manner in which a perfectly good valve may be burned on account of imperfect seating due to carbon on the valve seat, or improper adjustment.

As carburetors are adjusted for the heated condition, in order to obtain the proper mixture of vapor and air on starting, it is customary to use the choke or to otherwise alter temporarily the ratio of air to gasoline delivered to the engine.

Effects of Priming and Choking

To burn any gasoline efficiently in the modern automobile engine, it must be vaporized completely, otherwise the mixture will be excessively wet, crankcase dilution, carbon formation, etc., being a probable result. In fact, unless complete vaporization is brought about, priming or choking will be necessary in order to get an explosive mixture of gasoline and air.

In a cold engine less of the gasoline introduced by priming, etc., will vaporize than under usual running temperatures. As a result, considerably more of the heavy ends will remain in liquid state to leak past the piston rings, wash the film of lubricating oil from the cylinder walls, and work into the crankcase, where dilution of the lubricating oil will result.

Excessive Choking Inadvisable

Continued use of the choke to produce a relatively uniform flow of rich mixture to the engine, especially when warming up, would bring about the same objectionable results; therefore in using, the choke should be pulled all the way back until one or two explosions have taken place. Then it should be pushed in and the engine kept running by working the throttle until warming up is completed.

Unfortunately, priming and use of the choke are necessary evils in practically every instance of starting where the garage is unheated or the car is stored in the usual manner with perhaps only a robe thrown over the radiator.

Yet the motorist should resort to them as little as possible, if he has the welfare of his car at heart, and the engine should never be run at more than moderate speed until the lubricating oil has had time to be worked up onto the cylinder walls to replace that which may have been washed off by the liquid fuel as mentioned above.

An excessive amount of gasoline mixed with engine lubricating oil will reduce the viscosity or thin down the latter to such an extent that it may no longer be able to lubricate the engine properly. Addition of fresh oil will overcome this to some extent, though never to an absolutely satisfactory degree. The only positive remedy is to drain the crankcase, as is fully discussed later.

A very popular method of facilitating starting in certain localities where cold is extreme is to wring out a cloth in hot water and wrap it round the carburetor. In fact this procedure may become an absolute necessity in event of water having gained access to, and frozen in, the float chamber, thereby clogging the spray nozzle.

Covering the Radiator

Incomplete vaporization will be liable to occur only during the period of warming up, if proper covering is fitted to the radiator to keep the water at such a temperature (i. e. in the neighborhood of 150° F.) so that the engine will not run too cool.

Many motorists, however, operate continually with an unprotected radiator, unless the temperature drops to zero or below, with the idea that the engine heat will still counteract the lower water temperature.

In the neighborhood of 25° to 35° F. this might be true, but below these temperatures the engine may run too cool, vaporization of gasoline will not be complete, and excessive dilution of crankcase oil will occur, as explained above.

It is therefore safest to use the radiator cover continually throughout cold weather. This is

a mechanical device to cut down the frontal area of the radiator when the car is in operation, and cover the former entirely when the car is idle.

As a general rule a radiator cover does not involve any chance of the engine overheating, if it is kept open from one-half to its full area during the period the car is operated. Under such conditions enough of the frontal area of the radiator will remain covered to prevent the engine from running cold, and yet it will not overheat.

Water in the Gasoline

The presence of water in the gasoline should be carefully guarded against in cold weather operation, due to the possibility of its giving trouble by freezing in the gasoline pipe, carburetor, or even the bottom of the storage tank. Should a drop of water come in contact with the fine mesh strainer located in the fuel line it may entirely cover the mesh with a film. Freezing of this film which might happen even when immersed in the fuel, would cause a stoppage in the flow of gasoline perhaps even to the extent of shutting off the entire supply.

To locate the source of such trouble while out on the road might be a difficult matter, as the frozen film covering the screen may not be readily apparent to the eye, and considerable labor and time would no doubt be involved before the cause of the stoppage in the fuel line could be ascertained. Even if such a film of water did not freeze there would still be the possible objectionable feature of misfiring.

In the motor car storage tank, water could gain easy access were the filling cap left loose, the tank filled in the rain, or certain of the seams leaking.

Condensation a Factor

Another prevalent cause of water accumulation in the gasoline tank is condensation of the moisture in the air. This is especially liable to occur if the car is stored in a warm garage, and then driven out under excessively cold atmospheric temperatures. In the same manner a certain amount of water will be condensed in the crankcase.

Indication of Water

Water in the carburetor is indicated by misfiring. In this event the carburetor drain should be opened to remove any slugs of water that may be present. It would also be advisable for the motorist to thoroughly inspect his tank for the presence of water at the earliest opportunity, and to drain the gasoline from the system and strain it.

Carburetor Adjustment

Carburetor adjustment plays a most important part in connection with cold weather operation of the motor car. In fact, it is one of the most essential adjustments on the engine, and there is a marked difference between winter and summer settings.

Fig. 2—The stem and underside of the valve shown in Figure No. 1.—Note manner in which the seat or face of the valve has been burned away.

While the effort should always be made to run with as lean a mixture as possible, in cold weather the normal richness of the gas must be markedly increased. Were this not done, starting difficulties would be great and it would be necessary to use the choke almost continually, with the detrimental results noted above.

For this reason, the modern carburetor is built for suitable adjustment in order to vary the percentage of gas and air, as well as the temperature of the latter.

Improper adjustment of a carburetor may give rise to:

1. Loss of power.
2. An excessive consumption of gasoline.
3. A decidedly uneven running of the engine.
4. Carbon formation on pistons, valves and cylinder head.

Lubrication of the Engine

Crankcase dilution has been regarded as a function of the state of vaporization of the fuel.

In this connection, however, there is another detrimental feature that may frequently occur in cold weather operation: water accumulation in the crankcase, and the possibility of freezing

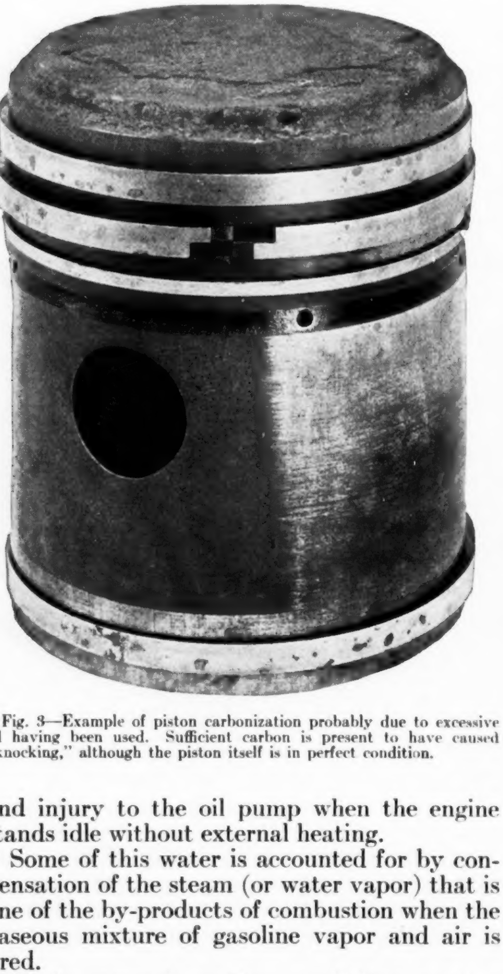


Fig. 3—Example of piston carbonization probably due to excessive oil having been used. Sufficient carbon is present to have caused "knocking," although the piston itself is in perfect condition.

and injury to the oil pump when the engine stands idle without external heating.

Some of this water is accounted for by condensation of the steam (or water vapor) that is one of the by-products of combustion when the gaseous mixture of gasoline vapor and air is fired.

Under normal weather conditions, with a sufficiently warm engine this steam will be emitted along with the other exhaust gases. In cold weather, however, particularly on starting or warming up a cold engine, or in event of the cooling water temperature being too low, part or all of this steam will be condensed through contact with the cold cylinder surfaces.

The resultant water will tend to leak past the piston rings and drain down into the crankcase to settle in a layer below the oil, usually surrounding the oil pump. If this accumulation becomes extensive, and if the car is stored or left standing for any length of time in an atmospheric temperature much below 32° F., in all probability the engine base will cool sufficiently to enable this water to freeze. This would render the oil pump screen inoperative or cause the pump to break, thus preventing oil circulation, which would result in burned out bearings and scored cylinders and pistons.

In addition expansion and contraction which will accompany such freezing and the subsequent melting may also possibly cause a fracture in the crankcase, which would involve considerable expense for welding and replacement.

On the other hand, if this water does not freeze, its presence will probably result in quite as serious a consequence, i.e., scored cylinders or burned out bearings, on account of lack of, or imperfect lubrication.

Water in excessive amount might, in extreme cases, entirely supplant the oil in the lubricating system. Even a small quantity may in some particular cases cause quite an emulsion, especially if an inferior grade of lubricating oil is used.

Draining the Crankcase

It is, therefore, essential to minimize both water accumulation, as well as dilution of lubricating oil in cold weather, by regularly changing the oil and draining the crankcase every 400 to 500 miles, or once a week if short trips are made.

It is evident that water accumulation and dilution can not be entirely guarded against, but frequent change to fresh oil will certainly reduce the possible detrimental effects.

Procedure when Flushing

It is usually good practice to wash the crankcase with a quart or two of warm light motor or flushing oil after draining, to remove sediment deposits from corners and other crevices. The use of kerosene as an engine wash is inadvisable due to the possibility of an excessive amount of it remaining in the crankcase. Very frequently the crankcase drain plugs are not located so that all the flushing oil can be readily and completely drained. With such engines it is generally advisable to use a light lubricating oil for flushing even though the expense may be slightly greater.

Turn the engine a few times by hand or with the self-starter, after adding flushing oil; never run it by its own power. Then drain off the latter, replace plug and add fresh motor oil.

Used motor oil, if not too dirty, can be used for certain chassis lubrication, or to thin out the transmission or differential lubricant.

It will always be advisable to drain the crankcase of used oil while the engine is hot, inasmuch as considerable of the sediment and other accumulations of foreign matter will be more completely drained out.

Care of a New or Rebored Engine

When breaking in a new engine, or one wherein the cylinders have been rebored, it will be generally advisable to drain and flush the crankcase after each 200 to 300 miles for the first 1000 miles of running, refilling the case each time with clean motor oil in the usual manner. During this period pour about a pint of lubricating oil into gas tank for every five gallons of gasoline used.

After these preliminary changes of oil the usual frequency of approximately every 400 to 500 miles can be followed out.

There is a very good practical reason for these first changes of oil and cleaning of the crankcase. In relatively every new engine, or instance of rebored cylinders, certain of the bearing surfaces will have a tendency to wear or polish off in the form of minute particles, to mix with the lubricating oil during the period over which the pistons and cylinders, or bearings and shafts, are worked into a smooth "running fit."

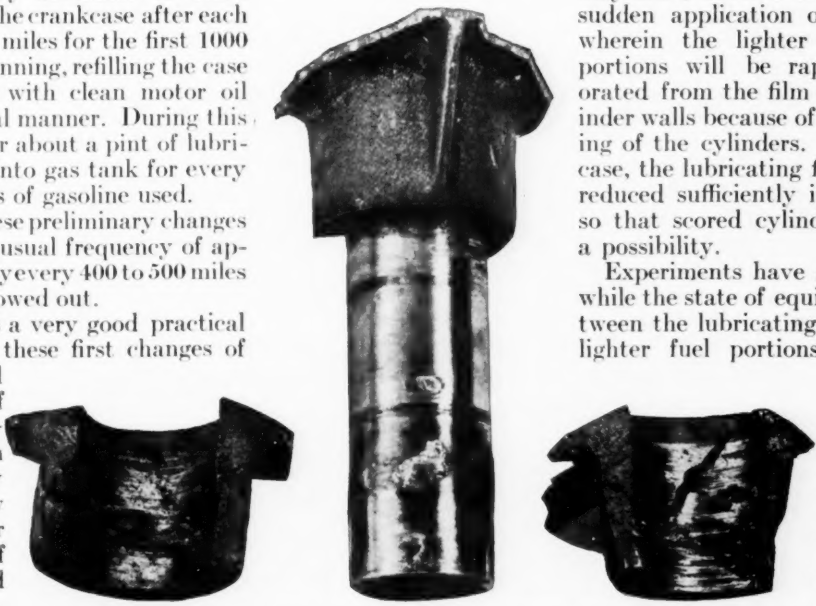


Fig. 4—Illustration showing the extent to which lack of lubrication may damage a wrist pin and its bearings. Note that portions of the bearings are actually welded to the wrist pin itself. It was necessary to break the piston to remove the pin.

It is perfectly evident that these particles will act as abrasives to cause rapid and abnormal wear of the engine bearings, cylinders, piston rings and other parts served by the lubricating oil, unless they are removed from the system.

The only effective way to remove them is to thoroughly drain and wash out the crankcase after the engine has operated a sufficient length of time, to insure that practically all of such free metal has been taken up by the lubricating oil.

Crankcase Dilution

In the average running of an automotive engine, crankcase dilution, or the reduction of the viscosity of the lubricating oil by unburned fuel, occurs at practically all times. It may be especially rapid in cold weather. Normally, however, it will go only so far, apparently reaching an equilibrium point after a sufficient length of time, notwithstanding the entry of a certain amount of the lighter diluents whenever the choke is used or priming resorted to.

On the other hand, if dilution for any reason, as by excessive use of the choke, becomes abnormal and the diluent is by far the major part of the lubricating mixture, a condition may arise, as for instance in the sudden application of the load, wherein the lighter or diluent portions will be rapidly evaporated from the film on the cylinder walls because of rapid heating of the cylinders. In such a case, the lubricating film may be reduced sufficiently in thickness so that scored cylinders will be a possibility.

Experiments have shown that while the state of equilibrium between the lubricating oil and the lighter fuel portions will vary with the nature of the constituents, it will balance itself of its own accord if sufficient time is allowed. That is, if an equilibrium condition of 20 per cent diluent was normal for the case in question, if 40 per cent diluent were started with in the crankcase, the lubricating mixture would tend to return to its state of equilibrium.

Effects on Bearings

The usual amount of reduction in viscosity due to dilution, in the average engine today may, of course, tend to promote the pumping of oil by journals in their rotation, inasmuch as lighter fluids will lend themselves to more ready handling, if it can be called such, but only under lower speeds. The higher the rubbing speeds the lower will be the pumping efficiency of the bearing. Furthermore, increase in the rubbing speed between a journal and bearing causes an increase in frictional heat.

As a result a diluted engine oil, under higher speeds and normal operating temperatures must possess very high lubricating ability and be as free as possible from carbon or other foreign matter if it is to furnish a suitable film to protect the bearings. **Only can this be**

obtained by the most careful refinement, and the rendering of the original oil as pure as possible.

Unless the oil is given every attention in its refinement there will be considerable possibility of it being broken down in service especially where the frictional heat developed in the bearing is not being adequately carried away by the oil itself. The ideal in automotive bearing construction is to plan for practically the entire removal of frictional heat by the oil, thereby preventing this heat from reaching either the bearing surface or journal. But this ideal is not practicably obtainable. Therefore the oil must be of such a character as to—

1. **Be capable of maintaining the requisite lubricating film.**
2. **Resist the breaking down effects of heat.**
3. **And develop as little gum and carbon as possible if subjected to continued service under overheated conditions.**

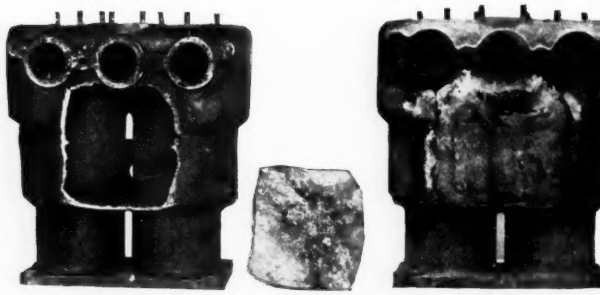
Carbon in an engine combustion chamber, on valves, piston heads, on spark plugs or in ring grooves, etc., is a detriment from the viewpoint of ultimate power developed. In bearing clearance spaces, however, it may in addition result in mechanical failures due to an impairment of circulation of the lubricant by the clogging of grooves or oil ducts. It must, therefore, be guarded against with the utmost care.

Carbon Formation

In connection with this matter of dilution, it is decidedly necessary to keep in mind the relation which it bears to excessive carbon formation, or the building up of so-called carbon deposits, not only on spark plugs, pistons, cylinder heads, around the rings, and on the valves and seats, but also in the crankcase or oil sump itself.

While carbon formation is more generally attributed to incomplete combustion of the fuel, to the use of excess lubricating oil or to the entry of silicious foreign matter such as, road dust via the air intake or breather pipe, we must not lose sight of the fact that dilution is also a pertinent contributor.

It is perfectly evident that the lighter the lubricant or the thinner the film on the cylinder walls, the more readily will it succumb to the wiping effects of the piston. This will, of course, increase the possibility of pumping or forcing of the lubricating film up into the combustion chamber where it will be ultimately burned. The direct result may be the development of more or less carbon.



A B

Courtesy of The Linde Air Products Company.

Fig. 5—A—Before the weld—Showing the extent to which a cylinder block may have to be "patched" in event of breakage due to frozen cooling mixture. B—After the weld—The "patch" in place,—the block ready for service once again.

The amount of this latter will, of course, depend upon the residual carbon content of the oil. Where the latter burns cleanly the extent of such deposits will be relatively small. **Furthermore, if the oil is properly refined and adapted to the purpose, such carbonaceous matter will be soft in appearance, low in quantity and comparatively easy of removal.**

Over extended periods of operation, however, carbon deposits, whatever their nature, will be bound to increase. Furthermore, where pumping or forcing of a certain amount of lubricating oil into the combustion chamber occurs, the ultimate oil consumption will be higher, with a reduction in the mileage developed per gallon. In addition, dilution may involve the possibility of a certain amount of loss of compression due to impairment of the piston seal when the viscosity of the oil is so reduced that the lubricating film is comparatively readily wiped off by the piston rings.

Insufficient Lubrication

If the oil level in the crankcase becomes too low by reason of carelessness, or an inoperative oil gauge, the engine may begin to pound, and overheat abnormally. To prevent serious damage to the engine, it should be stopped as soon as possible and allowed to cool.

An experienced operator will detect the loss of power and discern the cause before damage is done.

Fresh oil should then be added to bring the level up to normal.

Where damage may have occurred due to the necessity of running the engine under these conditions for any length of time, it will be advisable to have a thorough inspection made, if possible, before the car is again driven, to

make sure that bearings have not been scored or burned or cylinders and piston rings materially damaged.

Selection of Motor Oils

In cold weather the efficiency of any automotive engine from a lubricating viewpoint will be largely dependent upon the operating temperature, and viscosity of the motor oil used. Viscosity is essentially a function of the temperature. Hence it is evident that under colder atmospheric conditions the viscosity of a lubricant will increase, resulting in a lower degree of fluidity and involving greater internal fluid friction.

Naturally, this will cause a reduction in lubricating efficiency and necessitate a greater consumption of power to bring the car up to, and maintain it at the desired speeds.

If the normal viscosity of the oil at 100° F. is comparatively high it is perfectly clear that under exceedingly low temperatures this oil might become so sluggish as to be relatively difficult to pump. It is for this reason that lighter, lower viscosity motor oils are used in the winter than in the summer.

Importance of Low Pour Test

In the refining of motor oils, it is possible to vary the pour test or temperature of congealment to some extent. Naturally, the lower this temperature, or in other words, **the lower the pour test the more suitable and dependable will the oil be for cold weather operation,** other factors being equal. In view of this, the motorist should endeavor to obtain as low a pour test oil as possible for winter usage.

Viscosity also a Factor

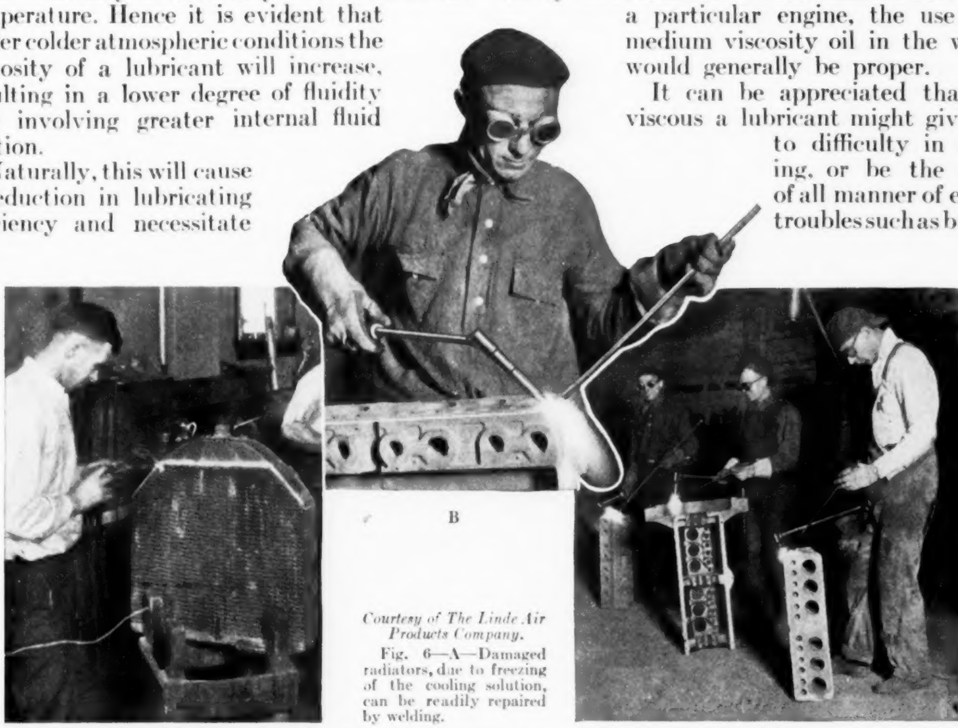
In general winter operation, the viscosity of the motor oil should be reduced so as to give approximately the same lubricating efficiency as in warm weather. For example, were a heavy oil recommended for summer service in a particular engine, the use of a medium viscosity oil in the winter would generally be proper.

It can be appreciated that too viscous a lubricant might give rise to difficulty in starting, or be the cause of all manner of engine troubles such as burned bearings, scored cylinders or seizing of certain parts, due to its being too viscous to be properly transmitted throughout the lubricating system.

In other words, any inability of the pump to lift this abnormally heavy oil, or any possibility of it being discharged back into the crankcase through the relief valve, may result in the engine operating for perhaps several minutes with practically no lubrication.

Do not rely on Crankcase Dilution

The claim may be advanced that the more or less common condition of crankcase dilution will soon cause the thinning down of such a lubricant to enable it to flow properly. Crankcase dilution, however, is an extensive variable, and it should never be depended upon to perform any such function. In fact even with



Courtesy of The Linde Air Products Company.

Fig. 6—A—Damaged radiators, due to freezing of the cooling solution, can be readily repaired by welding.

A B C

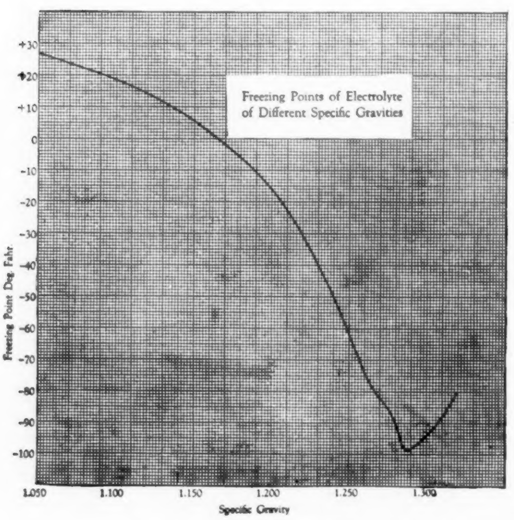
B, C—Welding operations being carried out on cylinder blocks and crankcase

proper use of the priming cup or choke it would be a very doubtful agent to rely upon for viscosity reduction, and much damage could be done before dilution to the extent required would take place when operating with a lubricant of too high a viscosity.

If, in the opinion of the operator, the atmospheric temperature is so low as to render an otherwise suitable motor oil temporarily so sluggish as to be incapable of proper lubrication, he should insure lubrication by warming up his cold engine very slowly, until the heat generated has reduced the viscosity of the oil sufficiently to enable proper pumping.

The Transmission and Differential

Inasmuch as the one lubricant must, as a rule, serve both gears and bearings in the motor car transmission and differential, it must be of sufficient viscosity to not only maintain



Courtesy of The Electric Storage Battery Company.

Fig. 7—Table indicating freezing point of storage battery electrolyte of different specific gravities. This is an especially helpful table for reference during cold weather operation of the motor car.

the requisite film of lubricant on the gear teeth but also have adequate penetrative ability to serve the bearings whatever their type or design.

Nature of the Lubricant

Such a lubricant should always have as low a pour test as possible where it is to be used under low temperature conditions. Many so-called compounded gear lubricants while admirably suited to warm weather service, are totally inadequate when temperatures drop below 40 to 50 degrees F. As a rule they "set" or congeal to such an extent that the gears will frequently cut a channel in the main body of the lubricant, thereby preventing it being carried to the teeth of the element above or distributed to the bearings.

In consequence, straight mineral lubricants will be best adapted to the gears of the average car. In cold weather a viscosity of approximately 115 seconds Saybolt at 210 degrees F. should be used. In warmer weather a viscosity of 200 seconds will be best. If refined from crudes of suitable base, especially to meet low temperature conditions, it is perfectly practicable to obtain such lubricants of as low a pour test as 15 to 20 degrees F.

Where Reduced Viscosity Is Desired

In certain cases of both transmission and differential lubrication, however, it may be found best to thin down such lubricants to approximately the correct viscosity for cold weather service, by the addition of a low pour test motor oil. Especially is this advantageous where temperatures are below the pour test of the lighter product mentioned above. In such instances, reduction of viscosity by means of a motor oil of approximately zero pour test will oftentimes solve an impending problem very satisfactorily. The amount of motor oil necessary will depend of course upon the severity of the weather and the possible temperatures that may be encountered.

Amount of Motor Oil Necessary

In general the addition of sufficient motor oil in an approximate ratio of two parts of gear lubricant to one part of oil will render the resultant lubricant in the gear case of the proper consistency. When this lubricant is thoroughly mixed or blended in the transmission and rear axle (which occurs automatically when the gears rotate) there will normally be sufficient flow in cold weather to insure lubrication of all gears and bearings, and it will have the added advantage of reducing the power necessary for starting.

The Chassis and Other Parts

In a consideration of such other parts of the motor car as require lubrication we will have to deal with the universal, the front and rear wheel bearings, the water circulating pump, the steering mechanism, spring shackle bolts, air springs (where employed), and the magneto bearings.

Pressures on chassis parts are more or less identical with those involved in heavy duty industrial machinery. Therefore the lubricants used must give a thick film.

Normally of all moving parts on such a vehicle, the chassis elements receive the least attention and are expected to run for a long time without much consideration.

The wear that is bound to occur in such a case is naturally great, and infinitely more important from a safety viewpoint. Failures of gearing or motor bearings would normally not result in more personal inconvenience than a severe jolting, before the car could be brought to a stop. Failure of the steering gear, however, or shearing of an axle and the loss of a wheel might very easily result in fatalities.

In cold weather operation chassis parts require more attention than in the summer time. Lubricating equipment is frequently exposed and the contents may easily become so congealed that all lubrication will cease for days at a time. No protective measures are available, hence the only recourse of the motorist is to make his inspections more frequently and with greater care. It will be to his advantage as well to use a lighter grade of cup grease for pressure grease fittings, etc., and the same grade of oil as in his engine for oil cups or a system involving automatic lubrication.

A B C

Courtesy of Willard Storage Battery Company.

Fig. 8—A—Group of battery plates showing the effect of lack of filling. B—An illustration of how a storage battery plate may be buckled due to improper care. C—An overheated group of battery plates caused by sulphation. Overheating in a storage battery is an especially important thing to guard against.

The Cooling System

To protect the cooling system in cold weather against freezing, and guard against radiator leaks, cracked cylinder blocks or a frozen water pump, the water must be mixed with a certain amount of alcohol, glycerine, etc., alcohol plus glycerine, or dissolved salts; or, a light grade of mineral oil can be substituted for such water mixtures. This latter is, however, chiefly confined to the heavy duty tractor.

In using such solutions the purpose, of course, is to lower the freezing point of the mixture in the radiator below the probable lowest atmospheric temperature likely to be encountered.

Essential Properties of Anti-Freezing Solutions

Whatever the nature of the anti-freezing compound, the ideal solution should have certain definite properties:

1. The ingredients used should be easily obtainable in operating localities.
2. There should be no possibility of freezing.
3. It should not be injurious to either the engine or the radiator through corrosion or electrolytic action, or to rubber hose connections.
4. It should not lose its non-freezing and non-congealing properties after continued use.
5. There should be the least possible fire hazard.
6. The boiling point of the solution should not differ materially from that of water.
7. It should have as constant a viscosity as possible through the entire temperature range it will be subjected to, and it should remain perfectly fluid and not tend to stop up any small openings in the system.
8. It should be able to conduct heat away as rapidly as possible.

The following table* giving the freezing points and specific gravities of certain anti-freezing solutions will be of decided interest in this regard.

Table Giving the Freezing Points and Specific Gravities of Certain Anti-Freezing Solutions

Solution	Percentage (by volume) in water, and freezing points.				
	10% °C °F	20% °C °F	30% °C °F	40% °C °F	50% °C °F
Denatured Alcohol (90% by vol.)	−3 +27 (0.988)	−7 +19 (0.978)	−12 +10 (0.968)	−19 −2 (0.957)	−28 −18 (0.943)
Wood Alcohol (97% by vol.)	−5 +23 (0.987)	−12 +10 (0.975)	−19 −2 (0.963)	−29 −20 (0.952)	−40 −40 (0.937)
Distilled Glycerine (95% by wt.)	−2 +29 (1.029)	−6 +21 (1.057)	−11 +12 (1.085)	−18 0 (1.112)	−26 −15 (1.140)
Ethylene Glycol (95% by wt.)	−3 +26 (1.016)	−9 +16 (1.031)	−16 +3 (1.045)	−24 −11 (1.058)	−35 −31 (1.070)

Use of Table

A typical example of the use of this table, assuming that the lowest temperature anticipated is 19° above zero Fahr., is as follows:

**If the radiator holds 3.5 gallons, 20% of this must be alcohol and the remaining 80% water. 20% of 3.5 gallons is 0.7 gal. or a little more than 5.5 pints which is the quantity required. This should be added to enough water to make 3.5 gallons; that is, the water used will be 3.5 gallons less 0.7 gal. or 2.8 gallons, a little more than 11 quarts.

Alcohol-Water

Alcohol-water anti-freezing mixtures have probably been most commonly used by the motorist to date, owing to the fact that alcohol is easily obtainable at reasonable cost. The grade used may be either denatured or wood alcohol.

Alcohol solutions do not have any greater tendency to corrode the metallic parts of the system than water alone. On the other hand wood alcohol will often contain free acetic acid. It is advisable as a result not to use wood alcohol unless it is definitely known to be acid free. The amount of alcohol used will affect the freezing point of the mixture, as is shown in the accompanying table.

Where using alcohol it is important to remember that this product will evaporate far more rapidly than water. Hence a certain amount must be added as make-up from time to time to keep the concentration of the mixture as desired. For this reason it is well to test the specific gravity of the alcohol mixture regularly with a hydrometer calibrated for temperature correction, and check the reading with the above table.

Alcohol, however, lowers the boiling point of water to quite an extent if used in large amounts. Consequently it may frequently happen that on a comparatively warm day when the engine is "idled" the solution will boil readily and abnormal evaporation will take place, thus raising the freezing point of the remaining mixture.

To overcome this tendency it is often preferred to use a mixture of equal parts of alcohol and glycerine, etc., as the anti-freeze component in the cooling water. The price of glycerine, however, may influence many people from using it for this purpose.

Glycerine and Ethylene Glycol

Glycerine, and ethylene glycol in contrast to alcohol, raise the boiling point of water, and thus they neutralize to some extent the effects of alcohol in this regard.

Glycerine, however, is claimed to be somewhat more injurious to the rubber connections

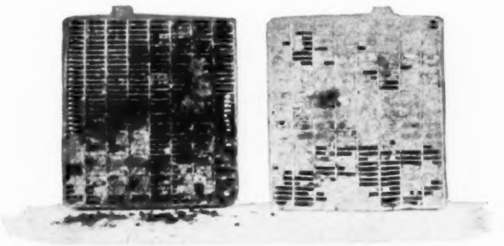
*The above table is from data developed by the Bureau of Standards.

**"Anti-Freezing Solutions," Journal of the Society of Automotive Engineers, Nov. 1921.

which are used between the radiator and engine. A glycerine-water mixture does not evaporate as readily as an alcohol mixture, so the cost and amount of ingredients used in renewing the solution will not be as great.

Saline Solutions

Saline solutions, made chiefly by dissolving common table salt or more frequently calcium or magnesium chloride in water, are sometimes used as anti-freezing mixtures in case alcohol or glycerine, etc., are unobtainable.



Courtesy of Willard Storage Battery Company.

Fig. 9—Plates from a frozen storage battery. The extent to which the plates may be damaged by allowing the battery to become too far discharged thereby raising the freezing point of the electrolyte, can be appreciated from examination of the above illustration. It is therefore advisable to test the specific gravity of the electrolyte regularly and observe the other precautions as outlined in this article and also emphasized by the storage battery builders. A properly charged storage battery is an adjunct to easy starting of the engine in cold weather and enables the use of the choke to be reduced as far as possible thereby reducing the possibility of the occurrence of abnormal crankcase dilution.

The principal advantage of such compounds is that they are non-volatile. On the other hand the use of such chemicals is never advisable except in an emergency, due to the possibility of troublesome consequences on account of these chlorides attacking the metallic parts of the system, especially if there is any solder or aluminum in the latter.

Mineral Oils also practicable

Kerosene or light lubricating oil may also be used as a cooling liquid. Opinion differs as to their value for this purpose. There are many instances of motor vehicles where kerosene or winter black oil has been successfully substituted for a water solution in winter service. As yet there is not enough data to warrant definite conclusions as to their efficiency.

Kerosene has a higher boiling point and a lower freezing point than water. Due to the fact that it has a comparatively high boiling point and a low specific heat, it is advantageous to use in cold weather, because it enables the engine to heat up more rapidly upon starting. Mineral oils in general have an injurious effect on rubber connections.

In tractor operation preliminary tests have indicated the use of oil as a cooling solution to be very satisfactory where kerosene is used as the fuel. Probably the most satisfactory viscosity of an oil for this service would be in the neighborhood of 100° Saybolt at 100° Fahr. It should be a product from such a crude, or so refined as to prevent possibility of crystallization of any of its constituents, such as paraffine, in the colder parts of the system where the engine stopped for any length of time, for this would cause uneven heating of the metallic surfaces.

In Case of Freezing

In event of freezing of the water or cooling solution at any time either through carelessness or sudden abnormal temperature drop, never try to thaw it out by running the engine. If possible, the garage should be heated or the car should be towed to a warm place. If this is impracticable it may be possible to thaw out the system by applying towels or rags wrung out in boiling water to as much of the cooling area as possible, though observing every care that no water drips upon any part of the ignition system.

Temperature Control—Radiator Protection

While it is most essential that the liquid in the cooling system be kept from freezing, it is also important that its temperature be controlled at least to some extent in order to enable the engine to operate at its best.

This subject has been briefly touched upon heretofore in connection with priming and choking, and the matter of thorough vaporization of the gasoline, when radiator covers were also discussed. These latter have three distinct advantages that should be remembered:

1. They keep the engine and radiator warm.
2. They make starting easier, and
3. They save the storage battery to a marked extent.

Use of the Thermostat

In order to aid in regulating the temperature of the cooling water, increase the thermal efficiency and reduce carbon deposits, the thermostat is a valuable adjunct in a cooling system.

By this device, free circulation of the cooling water is blocked from the cylinder cooling jackets until the temperature of the walls has reached the desired temperature for which the thermostat is set. Thus the walls and the cylinder head can be kept at a sufficiently high temperature to aid in the complete vaporization and burning of the gasoline.

In addition carbon deposits from any excess

lubricating oil will be reduced, due to the amount of oil that it is necessary to burn being decreased. Crankcase dilution is also materially cut down, as already discussed.

Automatic radiator shutters

Automatic radiator shutters are also used to serve this same purpose. These have the added advantage in maintaining a relatively uniform temperature in the air passing to the carburetor. Using a thermostatic control it is obvious that in certain instances the water passage might be so reduced that the air passing under the hood to the carburetor would take up relatively little heat, hence the temperature of the mixture might suffer a decided drop.

It is difficult to foretell to what extent the temperature under the hood and the operating temperature of the engine will vary over all year-round running. It is perfectly natural to assume, however, that if due precaution is taken to maintain the engine at its proper operating temperatures, there will be less necessity for changing the grade of oil used in the crankcase.

Care of the Storage Battery

The essential point involved in the care of the storage battery in cold weather operation is to maintain the battery solution at such a concentration that there will be as little danger as possible of its freezing.

The freezing point will depend entirely upon the specific gravity of the electrolyte; i.e., having given a solution the specific gravity of which is 1.250, there will be no danger of its freezing unless the temperature drops to the neighborhood of 62° below 0° F., which is of course very improbable. On the other hand, a solution having a specific gravity of 1.150 will have a freezing point in the neighborhood of 5° above 0° F. It is therefore evident that the battery should never be allowed to become run down or completely discharged, inasmuch as in this state there will be greater danger of freezing due to the reduced concentration of the liquid.

Consequently it is advisable to test the concentration of the battery solution by means of a hydrometer at least twice a month. In this connection the following information will be of interest:

Readings between 1.250 and 1.220 indicate that the battery is about half charged. If the car is equipped with an electric starter, lamps and starter should be used sparingly until the readings come up to the specific gravity as recommended by battery manufacturers, probably somewhere between 1.280 and 1.300. If there is no charging generator on the car, it is time to give the battery a bench charge.

Readings less than 1.170 indicate complete discharge; in this case the battery should be given a bench charge. Oftentimes this discharged condition may be due to need for adjustment in the electrical system.

If the reading of one cell differs from the others by 50 points or more, it indicates loss of electrolyte, wrongful addition of electrolyte or internal trouble in the battery. In event of this see a battery service station expert.

At all times the plates should be properly covered with the battery electrolyte. Due to the evaporation of the water constituent it will be necessary to add pure distilled water to maintain this condition. However, the rate of evaporation will be less in winter than in summer.

When it is necessary to add water in cold weather it should be done just before the car is started, in order to insure that the water will be properly mixed with the electrolyte. Otherwise, there will be possibility of a layer of pure water remaining on top of the electrolyte, to ultimately freeze if the temperature is low enough. Care should be taken not to add more water than required and not to spill electrolyte when reading gravities, as much damage may be done through corrosion of terminals, cases and hold-downs.

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